# Present and future mm-VLBI imaging of jets in AGN: the case of NRAO 150

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## The Global mm-VLBI Array: sensitive astronomy at 4 $\mu$as resolution

**• Recent 7 mm-VLBI highlights:**
During the last years, 7 mm-VLBI observations, at angular resolutions of ~0.15 mas, have addressed the triggering of relativistic jets in AGN and their hydrodynamics. Among these observations are the first estimations of the initial jet opening angle (in M 87, Junor et al. 1999), the distances from the jet's foot point to the central engine (in 3C 120, Marscher et al. 2002) and accurate data to test precession models (in BL Lac, Stirling et al. 2003) and to test relativistic hydrodynamic models (in 3C 120, Gómez et al. 2001).

**• Present 3 mm Global mm-VLBI Array capability:**
At present, 3 mm-VLBI offers an even more powerful tool to image the innermost jet regions. The lower jet opacities at this shorter wavelength allow one to probe innermost jet regions with resolution powers three times better than those at 7 mm.

Nowadays, the most sensitive 3 mm-VLBI instrument is the Global mm-VLBI Array (GMVA, see Fig. 1 and http://www.mpifr-bonn.mpg.de/div/vlbi/globalmm), which is able to achieve angular resolutions better than 40 $\mu$as with typical baseline sensitivities of 80-100 mJy (adopting 20 s coherence time, 100 s segmentation time and a recording rate of 512 Mbps). This yields image sensitivities of 1-2 mJy (for 12 h of observation and a duty cycle of 0.5).

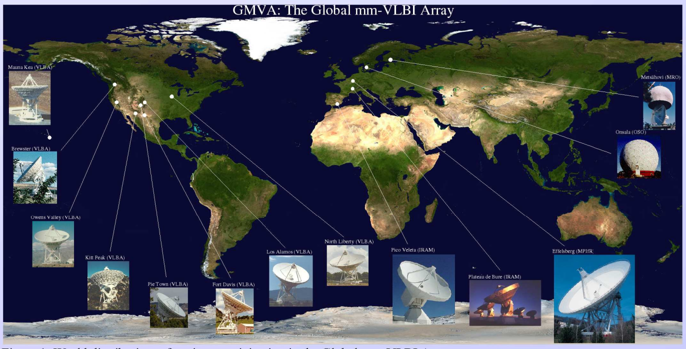


Figure 1. World distribution of stations participating in the Global mm-VLBI Array.

## NRAO 150: an unusual AGN "hidden" by the Milky Way

NRAO 150 is a strong compact radio source without optical identification due to Galactic absorption (Galactic latitude -1.6º). Although its distance to us is still unknown, we hope to determine its redshift through an ongoing spectroscopic project in the IR band, at which the source is not strongly absorbed.

The source has been monitored regularly in the radio and millimetre bands since the beginning of the eighties. Since then, its total flux density light curve has displayed a quasi-sinusoidal behaviour with a characteristic time-scale of 20-25 yr (see Fig. 2).

**•Strong outer to inner jet misalignment of 120º:**

On cm-VLBI scales, NRAO 150 shows a compact core plus a one-sided jet extending beyond 20 mas with a structural position angle of ~30º (see Fig. 3). Our new 7 mm-VLBI observations have produced a surprising view of the innermost jet, with a strong misalignment (of ~120º) within the first 0.5 mas (Fig. 3).

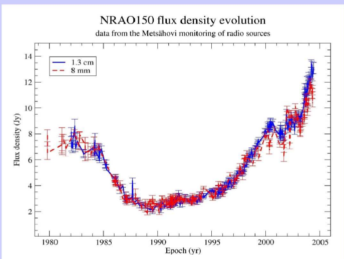


Figure 2. 1.3 cm and 8 mm flux density evolution of NRAO150 since 1979. Data taken from Teräsranta et al (2004).

**• The fastest AGN jet rotation at 7°/year:**
Making use of the Global mm-VLBI Array (and the former CMVA), we have monitored the innermost jet evolution since 1999 up to date with observations performed about every six months. Fig. 4 shows some of the resulting images from this observations, which demonstrate the capability of the GMVA to probe the innermost jet structures with angular resolutions better than 40 $\mu$as and dynamic ranges larger than 100.

The first results from this monitoring have revealed an even more intriguing phenomenon: a clear angular rotation of the innermost 0.5 mas jet (projected on the plane of the sky) with a speed of ~7°/year, which is so far the fastest reported (up to our knowledge) for an AGN jet.

These observations, have not only answered the question about the cause of the large jet misalignment found in NRAO 150, but they are also providing clues about the possible origin of the inner jet rotation.

References:
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- Garret, 2003, ASP Conf. Serr, 306, 3
- Gómez et al., 2001, ApJ, 561, L161
- Marscher et al., 2002, Nature, 417, 625
- Stirling et al., 2003, MNRAS, 341, 405
- Junor et al., 1999, Nature, 401, 891

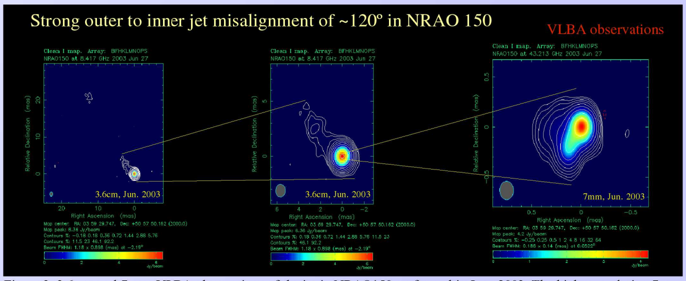


Figure 3. 3.6 cm and 7 mm VLBA observations of the jet in NRAO150 performed in June 2003. The higher resolution 7 mm image shows a strong misalignment between the cm and the mm jet of ~120º (Agudo et al. 2005).

## Is NRAO 150 a precessing system?

It is reasonable to think that the quasi-sinusoidal light curve of the source (Fig. 2), its extreme jet misalignment (Fig. 3) and the inner jet rotation (Fig. 3) are related. In this case, a possible explanation of the NRAO 150 evolution would be a precession-like motion of the inner 0.5 mas of the jet. This, together with projection effects and variable Doppler boosting through small viewing angles, could explain the strong jet misalignment, the jet rotation in the plane of the sky and the 20-25 yr variability time-scale of the radio light curves.

Although jet precession is a likely explanation to describe the source behaviour, it is not unique. Other kinds of large amplitude MHD instabilities at the jet foot point may also play an important role. In both cases, further high resolution observations of NRAO 150 (specially 3 mm-VLBI polarimetry) would place our understanding of the innermost jet physics on firmer ground.

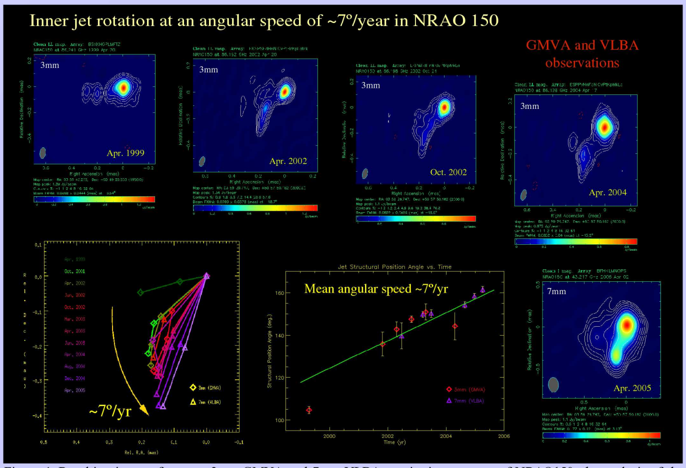


Figure 4. Resulting images from our 3mm-GMVA and 7mm-VLBA monitoring program of NRAO150. the analysis of the images reveals the direct detection of a fast change of the ejection direction of the jet with an angular speed (in the plane of the sky) of ~7º/yr (Agudo et al. 2005).

## The future Global mm-VLBI Array

**• Polarimetry, higher sensitivity and higher image fidelity:**
High sensitivity GMVA polarimetry is nowadays being tested through the NRAO 150 monitoring outlined above and is expected to become a standard technique during the next years. In addition, an increase in sensitivity is still needed for the GMVA in order to obtain better image qualities for a larger number of weak sources. The most direct way to do it, is to increase the collecting area. Through the participation of the new generation mm stations (among them ALMA, GBT, LMT, CARMA, Yebes, SMA, SRT and Nobeyama are some of the most sensitive) the GMVA will achieve baseline and image sensitivities of up to 13 times better than at present! Also continuous development of VLBI will provide during the next years standard recording rates of at least 2 Gbps (Garret 2003), which will increase the sensitivity by an extra factor ≥ √2. New stations will also largely improve the ($u$,$v$)-coverage and hence the image fidelity, allowing for imaging sources with declination lower than 20° (if ALMA joins the array).

**• Future science:**
If the proposed improvements are performed, dynamic ranges of a few thousand could be obtained. This would place mm-VLBI at a similar level of sensitivity than present day cm-VLBI, which would have an enormous impact on our knowledge of the physics of relativistic jets. It would be possible to obtain high quality polarimetric images of the innermost regions in jets, which would allow us to:

- investigate their MHD physics close to strong gravitational fields,
- study their triggering mechanisms,
- probe their initial magnetic field configurations,
- better constrain the properties of their accreting systems,

... for several hundreds or even thousands of jets in AGN.